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NATIONAL AERONAUTICAL AND SPACE ADMINISTRATION

GUIDE FOR PLANNING INVESTIGATIONS IN THE AMES 40- BY 80-FOOT WIND TUNNEL

OPERATED BY THE

LARGE-SCALE AERODYNAMICS BRANCH

August, 1972

MOFFETT FIELD, CALIFORNIA

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INTRODUCTION

The Ames 40- by 80-foot wind tunnel and its staff are primarily devoted to research. When it is in the national interest, however, development testing can be done. Approval for such testing for military projects requires the request of the cognizant branch of the Department of Defense. The wind tunnel is staffed and operated by the NASA.

This guide provides information to aid in the preliminary design of models for use in this wind tunnel. The information contained herein is subject to change without notice due to the continual evolution of techniques and test equipment. It is essential that the staff of the Large-Scale Aerodynamics Branch (LSAB) at Ames Research Center be consulted early during the planning of tests and designing of models. In no case should model construction be started before such consultation.

Special devices, such as equipment for remote operation of model or airplane engines and controls, are not enumerated in this guide. The LSAB staff should be consulted concerning any special needs.

THE WIND TUNNEL

General

The wind tunnel has a closed 40- by 80-foot test section with semicircular sides of 20-foot radius, and a closed-circuit air return passage. The general arrangement is shown in figure 1, and the test section and adjacent shop area are illustrated in figure 2.

The air is driven by six 40-foot-diameter fans which are powered by six 6,000-horsepower electric motors. The motor-generator system which supplies this power may be operated continuously at any power output up to a maximum of 30 megawatts.

Performance

Speed range:	0 to about 180 knots, continuously variable
Pressure, stagnation:	Atmospheric
Reynolds number:	0 to about $2x10^6$ per foot with standard atmospheric conditions (see fig. 3)
Temperature, stagnation:	Uncontrolled. Dependent upon seasonal atmospheric variations; also affected by operation of internal-combustion engines in models. Generally about 30°F to 120°F.

Dimensions

Test section:	40 feet high 80 feet wide at horizontal center line 80 feet long
Test-section doors:	40 feet wide by 49 feet long, one on each side of tunnel center line on top of tunnel. When open, a clear opening 80 feet by 49 feet is provided.

Hoist: A 15-ton and a 3-ton hoist mounted on a common bridge at the top of the test chamber are available to hoist models into the test section.

Elevator: From street level to test section, balance house, and top-of-tunnel levels. Load capacity is 2,500 pounds with a 6.5- by 7.0-foot area; doors are 6.5 feet wide and 7.0 feet high.

Model Support

Primary Support System.-

Type: Supported on two main struts and a collapsible tail strut which, in turn, are supported on a frame below the tunnel floor (see fig. 2). Main struts can be moved streamwise and cross-streamwise, tail strut can be moved cross-streamwise to permit yaw of model. Angle of attack of model is controlled by collapsing and extending tail strut.

Angle of attack: Range may be limited by any one of three conditions; namely (1) angular limitations of the ball sockets (see fig. 4(a)), (2) the maximum and minimum heights of the tail strut (further affected by tail length)(see fig. 4(b)), and (3) physical clearances within the test section for larger models. The main-strut ball and socket limits of $\pm 22.5^{\circ}$ can be offset any amount up to $\pm 20^{\circ}$ by insertion of wedges at the model-attachment pads. Limits for any proposed arrangement can be determined from the information given in figure 4.

Angle of yaw: Limitations upon the angle-of-yaw range are imposed by the available streamwise and cross-streamwise motion of the main struts (also affected by the strut tread) or by the maximum angle of inclination of the tail strut streamwise (also affected by the tail length). These limitations, along with the possible arrangements of strut position, are shown in figure 4(b). Note that several positions of the main struts are available to accommodate various treads and tail lengths. The center of rotation for yaw is midway between the main struts. The angle-of-attack range at any yaw angle is limited as described in the previous section.

Allowable strut loads: The tail strut is mounted in a gimbal and, hence, cannot transmit side, drag, or thrust loads. Various combinations of aerodynamic loadings (plus model dead weight) must be examined to estimate the resultant loads on the support struts. For example, model rolling moments are reacted by an incremental upload on one main strut and an equal download on the other; the resultant vertical load on a main strut will include components due to model weight, lift, pitching moment, and rolling moment.

Allowable loads per strut, lb

Strut	Down	Up	Side	Drag	Thrust
Main(each)	35,000	15,000	4,000	8,000	8,000
Tail	18,000	18,000	-	-	-

Balance system capacities: The transfer of strut loads to the scales through the balance frame system is illustrated schematically in figure 5. Mechanical lever systems transmit the lift tube, drag link, and side force link loads to seven scales with the following functions and capacities:

Scale	Total Range lb	Unloaded, or "mid-dial" position, lb	Function
Front lift	102,000	60,000	Left plus right front lift tube
Rear lift	102,000	60,000	Left plus right rear lift tube
Drag	32,400	15,200	Drag link
Front side force	16,400	9,200	Front side force link
Rear side force	16,400	9,200	Rear side force link
Front roll	266,000 x ~~270,000 ′-#~~	8,000	Right minus left front lift tube
Rear roll	266,000	8,000	Right minus left rear lift tube

442000 each

884000 ′-#

In addition to the direct scale forces shown in the table, are the following interactions: Moments due to drag forces acting above the drag restraint link are opposed by an equal opposing couple in the front and rear lift scales. Similarly, moments due to side forces are opposed by a couple in the roll scales.

Alternate support systems.- A variety of alternate support systems exist, and others can be fabricated for use on special tests. Where the primary system described above does not appear suitable, inquiries to the Large-Scale Aerodynamics Branch staff are invited.

Existing alternate systems:

1) Tripod mount for helicopter rotor tests
2) Floor-mounted turntable for semispan models
3) Various fixed-length struts for ground-effects tests
4) Arrangements for parachute tests

Operating Characteristics

The range of test conditions available with the primary model support system is presented in figure 6. Maximum allowable fan speed is 290 rpm, and maximum allowable power is 30 megawatts. The conditions shown apply without a model installed; model blockage will increase the power required at any given tunnel speed. There is a range of tunnel drive fan rpm's where severe structural vibration is encountered; continuous operation in this region is to be avoided.

The tunnel drive is equipped with an emergency stop circuit. The rates of reduction of dynamic pressure for the normal and emergency-stop methods are compared in figure 7. The emergency stop method can exceed the limit rate of power decrease specified for the power system which supplies Ames; use of this procedure is therefore reserved for extreme emergencies.

AUXILIARY FACILITIES

Shops and Offices

Shop and office space generally can be provided to meet the needs of Contractors' representatives.

Utilities

The following utilities are available in the test chamber and shops:

Electric power:

60 cycle a.c.
- Miscellaneous 120/208/460 volt outlets to building ground
- 120 volt, 20-amp outlets in test control room to balance-frame ground

M.G. set No. 1
- A.c. output, 120/208 volt, 400 cycle, 3 phase, 104 amp.
  400 cycle, single phase
- D.c. Output, 28 volt, 500 amp.

M.G. set No. 2
- 12 volt d.c., 1.5 kw
- 24 volt d.c., 3.0 kw

Portable set
- 24 to 30 volt d.c., 7.5 kw

Intermittent use (e.g., jet engine electric starters)
- 28 volt d.c., approx. 1800 amps for 30 sec.

Variable frequency, three phase
- 0 to 150 cycles, 2120 kva
- 0 to 400 cycles, 706 kva (2 sets)
- Arrangements for use of this variable-frequency power must be made at least two months in advance.

Compressed air:

125 psi, sufficient for hand tools

Hydraulic fluid:

32 gallons per minute maximum output at regulated pressures up to 3,000 psi continuous, 5,000 psi intermittent use.

Model Motors

The model motors currently owned by Ames are listed in table I. Availability must be checked in each instance.

Fuel Supply

Either gasoline or JP-type fuel can be supplied for the operation of internal-combustion engines in the test section. The limits of flow rate are: for gasoline, 25 gallons per minute at 80 pounds per square inch; and for JP-type fuel, 50 gallons per minute at 100 pounds per square inch. Suitable means are provided in the systems for pressure reduction. Arrangements for fuel requirements should be made at the earliest possible date.

Model-Handling Equipment

A 10-ton and a 6-1/2-ton hoist are available for handling large components for model assembly in the shop area prior to installation in the wind tunnel. The complete model is hoisted into the test section by the 15-ton hoist mentioned previously.

INSTRUMENTATION

General

In order to ensure compatibility of instrumentation methods and equipment, it is essential that the LSAB staff be consulted early in the planning of test instrumentation. In no case should implementation of an instrument plan be started prior to such consultation. A complete instrumentation book for the model must be prepared showing in detail the components instrumented, instruments used, circuit diagrams, and calibrations for the instruments. This instrumentation book shall arrive at the wind tunnel no later than the delivery date of the model.

Balances

A "floating frame" system of beam balances is used to measure all six components of forces and moments on the complete model. A schematic representation of the general arrangement is shown in figure 5. It should be noted that the floating frame is electrically insulated from the surrounding tunnel structure. Mechanical fouling between the floating frame and other structure is detected by checking for electrical continuity. Electrical power for model instrumentation is grounded to the floating frame by using isolation transformers and special outlets in the control room. All instrumentation wiring must be insulated from the tunnel structure from the model to the control room.

Several sets of 2-component load cells are available with normal-force capacities from 800 to 15,000 pounds, and axial-force capacities from 800 to 12,000 pounds. These balances were designed to measure model loads in the X-Z plane, but may be utilized for varied special purposes.

Data Acquisition

Three major instrumentation systems are installed in the control room of the wind tunnel (fig. 8). These are described in the following sections.

Data Acquisition System I (Datex I) is used to record and monitor the basic 6-component aerodynamic force and moment data. These data are normally obtained from the scale beam-balance system or from strain-gaged loads cells installed at the support-strut tips. Output data are digitized and recorded on punched cards. Up to 10 cards (samples) can be recorded at each test condition, and the data recorded on the last sample are printed by an automatic typewriter. Two or three 3-digit data channels are normally available for digitizing and recording other d.c. analog information.

When the Datex I is used to record scale beam-balance data, it has the sensitivities shown in table II. The optical scanners are used for data acquisition, and printed paper tapes are used as a back-up system.

Data Acquisition System II (Datex II) is used for digitizing, displaying, and recording large quantities of ancillary data such as pressures and temperatures. It accepts analog d.c. inputs and produces punched cards as output. The Datex II has a maximum capacity of 480 distinct inputs, which are recorded 10 at a time on 48 cards.

All the analog input signals are routed through an Analog Program Board (APB). With the APB, the inputs are programmed into 10 Steppers, each of which commutates up to 48 inputs, allowing the maximum capacity of 480 analog inputs. Each Stepper output drives a Strip Chart Recorder. The Recorders are used to record the Stepper output valves as a function of time, and to mechanically drive a shaft-type analog-to-digital converter.

The Datex II System is most frequently used for recording pressures. For this application it is used with "Scanivalves", which are pressure commutating transducers. Where these are used, the appropriate Steppers in the Datex II are disabled, and up to 48 pressures are commutated by the Scanivalve, in synchronization with the Steppers in use.

System specifications are given in table III. Detailed operational information is available from the LSAB staff.

Analog Tape Recorder.- The 14-channel F.M. analog tape recorder system is available for recording and monitoring dynamic data in the frequency range of d.c. to 10,000 Hz. Voice and time code information can be recorded on the two annotation tracks.

Three 5-inch and seven 1 X 3-inch oscilloscopes, three peak-to-peak indicators, and three average-level indicators are provided for monitoring either input or recorded data. For signal conditioning 13 high common-mode-noise-rejection, variable gain, differential amplifiers are available.

Tape recorder and amplifier specifications are given in table IV. The tape speeds presently available are 7-1/2 and 30 ips. However, if other F.M. center frequency electronics are provided by the contractor, other tape speeds can be used.

Auxiliary Instrumentation

In addition to the three systems previously discussed, the usual portable instruments are available. These include oscillographs, frequency counters, digital voltmeters, strain gage power supplies, and bridge balance boxes.

Special Requirements

Instrumentation and control system electric power must be obtained from the special instrument power outlets in the control room. If these systems are grounded to equipment which is not connected to the model, the mounting-strut/fairing foul system will not operate. (See discussion on Balances above.)

Wires from the model to the control room must be 125 to 150 feet long, depending on where they must reach within the control room. These leads from the model shall be no less than 30 feet long to the first connector (This will place the connectors on the balance frame beneath the strut fairings for easy access). Shielding against electrical noise is very important in such long wires. The LSAB staff should be contacted regarding shielding requirements. This problem and several solutions are discussed in Instrumentation Grounding and Noise Minimization Handbook, AFRPL-TR-65-1. In general, data wires should consist of twisted shielded pairs with the shields insulated. Thus each shield can be grounded at its appropriate point.

Model and Flow Visualization

Facilities for model illumination are provided. Normally, the model can be observed during tests from either side and from above the test section. When safety demands it, most of the direct viewing windows will be covered with armor plate, and up to four closed-circuit television circuits will be provided for visual monitoring of the model; one of these can be continuously recorded on video-tape.

Provisions can usually be made for necessary movie and/or still camera photographs of the model during tests; such photographic coverage should be arranged for as far in advance of tunnel entry as possible.

Six 80-tube water manometers, two 80-tube alkazene manometers, and one 36-tube mercury manometer are normally available. These may be used in lieu of, or in conjunction with, Datex II for pressure data. The working height is 54 inches. The scales have 0.10-inch divisions. Recording is by photography.

Data Reduction

The Datex I force and moment data are normally reduced on the LSAB SEL-840 digital computer. A remote link to the Center's IBM 360 digital system is also available, but often requires a significant turn-around time. An X-Y plotter is available for quick preliminary graphical display of test results, either by direct link to the SEL-840 or by use of a remote link commercial time sharing system.

Data reduction programs for the Datex I data applicable to aircraft, helicopter, and propeller test models are available. These programs produce tabulated aerodynamic coefficients, and may be computed about any of the commonly used axes. Pressure data recorded with the Datex II can be reduced to $(P-P_S)/q$ or P/q type coefficients, and integrations of these can be performed by available programs. Reduction of Datex II data other than pressures must be provided for by the Contractor.

Treatment of data recorded on the F.M. analog tape system or on oscillographs, and all manually recorded data will be arranged on an individual basis for each test.

MODEL REQUIREMENTS

Reliability

There is always a large backlog of urgent work for this wind tunnel. It is especially important, therefore, that models and their instruments be reliable so as to avoid delays and repetition of runs.

Environment

The ambient temperature in the tunnel is uncontrolled and varies with the seasons from as low as 30°F to as high as 120°F. During a test run, the tunnel temperature may increase as much as about 30°F with unpowered models. Test runs with internal combustion engines operating are terminated when the tunnel temperature reaches about 130°F. The model structure and the mechanisms and instrumentation within the model must function reliably over this temperature range. Particular attention must be given to protection of instrumentation and wiring in proximity to engine combustion and exhaust systems.

The total pressure of the air stream is atmospheric at all speeds. The static pressure and the dynamic pressure are those resulting from adiabatic flow from atmospheric static pressure and zero speed. The density ratio, temperature ratio, and stream velocity are shown as functions of the dynamic pressure in figure 6.

Size Limitations

Span:	72 feet (maximum test-section width, 80 feet)
Wing area:	Approximately 600 square feet
Length:	60 feet
Weight:	30,000 pounds (additional restrictions when using alternate support systems)

The first two items are governed by the reliability of blocking and tunnel-wall corrections necessary for the reduction of the data. If exceeded, results will be questionable. The wind-tunnel staff should be contacted for advice on any contemplated models which would exceed these limitations.

Model Power and Control

Models are controlled from the control room shown in figures 2 and 8. Provision has been made for power cables, fuel lines, and control leads within the fairings which enclose the primary support system struts. Ames will supply all fuel lines and heavy electrical power leads up to the model. The Contractor shall supply leads for control units and the control panel. These leads must be 125 feet long, and (as also specified for instrumentation wires) there shall be no connectors within the first 30 feet from the model. Since the space available for leads within the fairings is limited, all proposals for use of fuel, power, and control should be forwarded to the LSAB staff, together with the needs for instrumentation, for approval prior to fabrication of the lines and cables. It is generally necessary to divide these leads among the three struts, and this should be considered when designing the point(s) of entry into the model. Fuel lines and electrical leads carrying any significant voltage must be well separated within the model, and shall enter the model via different struts.

Starter requirements for models using jet engines should be discussed with the LSAB staff as early as possible. Electric starter power is available for moderate starting torque requirements. Special arrangements must be made in each case for air-start systems.

Leads for Pressure Data

Plans for obtaining pressure data from surface orifices, rakes, and probes should be discussed with the LSAB staff at the earliest possible date. If these data are to be recorded with the Datex **II** system, Ames can usually supply the required scanivalves and leads to the model. If the pressures are to be observed on manometer boards, Ames will supply pressure tubing to the model. In either case, the Contractor will be required to provide leads to the point(s) of mating and compatible with Ames equipment. The mating point(s) shall be either inside the model, or at least 30 feet from the model (see discussion regarding instrumentaion wires). Connections to the scanivalve units require 0.063-inch I.D. flexible tubing. For leads to manometer boards Ames will provide quick-connect fittings with 1/16-inch O.D. copper tubes in groups of 20 per fitting.

Information to be Supplied by the Contractor

Drawings.- Preliminary drawings or sketches should be submitted for comments at the earliest possible date. Final drawings showing all details of model construction, and details of all supporting equipment furnished by the Contractor, shall be delivered to the Ames LSAB no later than the model. Any instructions helpful in the assembly and use of the model shall be included.

Computing information.- All areas, moment arms, moment-center locations, tail lengths, mean aerodynamic chords, spans and other geometric information needed for computing coefficients or analyzing the test results shall be supplied not later than the model-delivery date. All pertinent reference data, such as the incidences of all wing and tail surfaces, locations of pressure orifices, and so on, shall be included.

Templates.- Templates suitable for checking the contours of any surfaces which may be subject to change during the investigation, and for setting and checking the angles of all movable or adjustable surfaces shall be delivered with the model.

Calibrations.- Calibrations of all Contractor-furnished instrumentation such as strain gages or position indicators shall be delivered at least as early as delivery of the device itself. It is the policy of the LSAB staff to check these calibrations and to check the functioning of all such devices before installation in the wind tunnel. The Contractor shall furnish loading yokes, gages, or other equipment needed to facilitate such checking.

Attachment pads.- Model attachment pads conforming to the typical arrangement shown in figure 4(a) shall arrive at the Laboratory no later than three weeks before the model is scheduled for the tunnel. These pads should be removable from the model and shall cover at least the shaded area shown in figure 4(a).

Fuel requirements.- The type, quantity, and flow rate of fuel required for the operation of internal-combustion engines shall be made known to the LSAB staff at the earliest possible date. The costs for such fuel are to be borne by the Contractor or the sponsoring agency.

Safety analysis.- A safety analysis report is required. (see the Systems Safety Analysis section.)

Delivery

Models, complete in all respects, and associated equipment and information shall be delivered in advance of the scheduled test date, allowing sufficient time for checking the model, calibration of instrumentation, assembly, and installation and/or checking connectors on electrical wiring and pressure leads. The length of time required will vary with the complexity of the model.

Unpowered models.- Delivery at least two weeks prior to test date.

Powered models.- Models incorporating power systems for primary (lift/thrust) or auxiliary purposes (such as for boundary-layer-control) must be functionally checked before tunnel entry. If electric motors are used, the functional checks will be made in the shop area of the wind tunnel. If internal-combustion engines are used, the model will be mounted on the LSAB outdoor Static Test Facility. In the latter case, consideration will be given to the advisability of mounting the model on load cells and recording test data at zero airspeed conditions. Thrust calibrations, ground effects, noise measurements, and control effectiveness data can be made at this facility which may usefully supplement the wind-tunnel test program and/or reduce the test time required in the wind tunnel.

The time required to accomplish functional checks on powered models will be at least three weeks, but will be determined for each model in consultation with the LSAB staff.

TEST PROGRAM

General

There is a continual demand for occupancy time for this wind tunnel, and test programs are scheduled at least six months in advance. Occupancy time for each program is assigned on a calendar-day basis, not by tunnel operating time. Hook-up and calibration time, time to make model configuration changes, possible delays associated with model and tunnel equipment malfunctions, instrumentation problems, etc., all reduce the balance of time available for testing. The wind tunnel normally operates two shifts per day, five days per week. Thus, it is necessary to plan each test program carefully for the best use of the allotted time.

Schedule of Tests

The Contractor shall submit a preliminary schedule of proposed tests at least one month in advance of the scheduled test date for review by the LSAB staff. It is advisable to assign priorities to the proposed test conditions to aid in formulating the final test schedule, and also to assure an efficient chronological scheduling of test runs in the event of unusual delays in the progress of testing or failure of the model before the tests are completed. All proposed test runs shall meet with Ames' approval in preparing the final test schedule.

Authority During Test Operations

During actual test operation, the Ames shift engineer shall supervise the testing, with the authority to deviate from the test schedule when in his judgment it is appropriate to do so. Either the Ames shift engineer or the Contractor shall have the authority to limit or terminate a test run should the safety or integrity of the model appear to be in danger.

Treatment of Data

There shall be a continuing and free exchange of data gathered by Ames and by the Contractor during the tests. Ames will assume technical ownership of <u>all</u> data (including photographic coverage) and the rights to publish the data through the usual NASA procedures unless specific agreements to the contrary are made prior to the tests. The intent of this statement is to place the burden of disclosure of all proprietary and/or classification restraints upon the Contractor. Early discussions of such restraints will assure preparations for any requirements for special handling of the data, and will allow Ames to properly assess its position in support of the proposed program.

SYSTEMS SAFETY ANALYSIS

A safety engineering analysis of a proposed test system, operating within prescribed test envelopes, shall be made in sufficient depth to assure maximum safety consistent with operational requirements. The extent of the analysis required will vary widely according to the nature and complexity of the potential hazards in each specific test system. A meeting shall be held with the Ames LSAB at the earliest practical date to establish the exact safety analysis requirements for the system proposed. The results of the analysis, and changes and/or modifications made in the test system to meet the requirements, must be submitted in writing to the LSAB staff, and approval obtained, 30 days prior to scheduled entry into the wind tunnel.

Each test system must be reviewed in detail to disclose all safety considerations pertinent to the specific system. A test system encompasses the model and its components, interfacing subsystems, equipment, instrumentation, and test crews. Facets involved in a system safety analysis are outlined below. Because of the variety of proposed test systems, these cannot be regarded as either complete or applicable to each test. The specific requirements to be met must in each instance be established by agreement with the LSAB staff.

Gross Hazard Study

A gross hazard analysis shall be conducted. This study is a comprehensive, qualitative, non-mathematical assessment of the safety features of the test system. Areas to be considered may include, but not be limited to, the following:

1) The complete model design shall be reviewed to identify all critical elements which must be subjected to detailed loads/stress analysis. This shall be done as early as practical in order to obtain NASA approval on 1) the scope of the analysis, 2) whether steady-state or dynamic considerations shall dictate the nature of the analyses, and 3) the particular analytic techniques to be used (see Specific Requirements).

2) Identification of energy sources, including those that might be released in the event of model failures (see Specific Requirements).

3) Fuels and propellants: their characteristics; hazard levels; handling, control, and usage safety features (see Specific Requirements).

4) Proposed system environmental restraints, e.g.:
   a) Remote control of power and controls,
   b) response times of variable parameters,
   c) limited visibility of test model.

5) Human factors, e.g.:
   a) Familiarity of operators with the test system,
   b) interfaces between NASA/Contractor personnel,
   c) interfaces between disciplines (operator/aerodynamicist/dynamicist/technicians) including the "language barriers",
   d) divisions of responsibility and authority under emergency situations,
   e) training pertaining to safe operation and maintenance of the system (see Specific Requirements).

6) Probable nature and impact of system equipment failure including model power and controls, and tunnel drive and attitude controls.

7) Compatibility of materials including such considerations as:
   a) Proximity of fuel and electrical wiring,
   b) temperature environment on instrumentation sensors and lead wires,
   c) deleterious effects of leakage of fuel/lubricants throughout the system.
   d) Toxic materials identified and safety provisions made.

8) Hazards of procedural changes, e.g.:
   a) Deviating from a specified test schedule,
   b) deviating from a specified test start/stop procedure,
   c) importance of monitoring specific test parameters (such as instrumented stresses, loads, positions, speeds, powers): which are required to be functioning properly for safe operation,
   d) changes in crew such as altering the number of operators/monitors, changing crews while a test is in progress, or providing temporary substitutes for specific tasks,
   e) improper procedural action by operators.

9) Sequential failures: With an assumed initial failure, the system shall be analyzed for hazards in the failed system, interfacing subsystems, equipment, and components; and shall include the effects of probable operator's reactions to the initial failure.

Specific Requirements

Model Strength.-

1) Steady-state loads.- The ultimate strength of critical elements of models shall be at least five times, and the yield strength shall be at least three times, the maximum steady-state loads anticipated. Static tests of the strength may be substituted for complete analysis when desired, and they may be required by the LSAB staff where the reliability of calculation appears uncertain. In the case of production airplanes which have been stressed to the standards of the FAA or the cognizant military authority only the support attachment hardware need be stressed to the above safety factors. Exceptions will also be made in those instances where it is recognized that normal safety factors are incompatible with other design demands, such as in propeller and rotor blade design. It shall be the responsibility of the Contractor to identify all such cases, and to receive NASA approval for these exceptions.

2) Dynamic loads.- In many cases, dynamic modes of model or model component motion, loads, and/or stresses will dictate the nature of the strength analysis. Test load limitations may be based on fatigue life under cyclic loading conditions rather than upon yield or ultimate material strength. In such cases the basis for assigning load limitations shall be clearly described and submitted for approval.

Fire Protection.- In models with internal-combustion engines, the Contractor shall supply an integral fire-extinguishing system, or shall contact the LSAB staff for advice regarding utilization of the tunnel fire-extinguishing system for this purpose. The tunnel system is of the carbon-dioxide type and is designed to protect the balance room and test section against fuel fires. Auxiliary fittings are provided to which the model lines may be attached.

If the model is an aircraft with integral fuel tanks, these tanks shall be filled with an inert gas under a small positive gage pressure during the wind tunnel tests.

Fragmentation Energy Levels.- The total system shall be reviewed to identify energy sources, especially those that might be released in the event of a model failure. Examples of such energy sources include rotors, propellers, fans, pressure vessels, and explosive cartridges. During testing, the primary dangers to personnel arise from high energy fragments released as a result of such model failures. The energy level, and the range of directions possible, at the time of release shall be documented. The energy level shall be expressed as $\frac{W}{A}\left(\frac{V}{1000}\right)^2$, $\frac{lb}{in^2}\left(\frac{ft}{sec}\right)^2$, where

W = weight of unit in lb
V = velocity at instant of separation, ft/sec
A = minimum cross-sectional area of unit, in^2

Details of the calculations, and the quantities W, V, and A shall be included in the documentation. The data will be judged in terms of the liklihood of injury to personnel. Corrective measures may be required to assure a satisfactory level of personnel safety.

Fail-Safe Controls.- Loss of primary power (electrical or hydraulic) to model controls can precipitate failures unless fail-safe systems are used; such as self-locking mechanical screws, the use of check valves, or closed-circuit hydraulics. Such fail-safe features are required unless the Contractor can prove that testing will be safe without such features.

Dynamic Stability.- Dynamic stability analyses shall be performed for tests which may involve aeroelastic or dynamic instabilities. A written summary of these analyses shall be furnished for review at least two months prior to the tests. The summary should show the type of analysis, main assumptions used, and the results. The results should include (1) the dynamic modes, (2) the level of stability as the stability boundaries are approached, and (3) loads on critical structural members. In case more information is desired, the detailed analyses shall be available on request. Proprietary rights will be respected.

Envelope of Test Operations.- Boundary conditions for safe test operations shall be determined, and the criteria for each boundary shall be defined. The predicted values of the test parameters most descriptive of the proximity of operating conditions to these boundaries must be presented in the form of graphical plots as part of the required safety analysis report.

Crew Training.- For those test systems where the safety of test operations may at times be dependent upon the experience or reaction times of the operating crew, simulation training may be required prior to the start of the tests. The need for such training and the nature and extent of the training will be established in consultation with the LSAB staff.

Safety Aids

All components and equipment associated with possible system failure modes shall be considered for re-design or supplementary aids to enhance test safety. Such methods as the following shall be considered:

1) Redundancy, such as parallel servos or hydraulics for critical controls, either of which has sufficient power to do the job.

2) Fail-safe features (see Specific Requirements).

3) Automatic warning, such as panel warning lights actuated by sensors on limit load, stress, speed, or temperature on critical components.

4) Automatic lock-out in lieu of warning.

5) Instrumentation duplication, such as for sensors measuring critical parameters, and in readout displays of these parameters.

Reporting

The required written submittal of the scope and results of the safety analyses may be an assemblage of notes, letters, company memos, etc; i.e., it is not required that a formal report be especially prepared to satisfy this requirement. In fact, it is urged that results of the various portions of the safety analyses be submitted as they become available, each in the form most convenient or expedient to the Contractor. This will minimize the possibility of a delay in the test date should any changes or extensions be judged necessary by NASA. The report shall include the static and dynamic analyses (made to establish the model strength characteristics) in abbreviated form with only enough detail to demonstrate the adequacy of the procedures. The Contractor shall be prepared to describe the analytical procedures in their entirety if requested by NASA.

Test Readiness Review

Preparation of a standard LSAB Test Readiness Review form will be initiated by the Ames project engineer. This form is a safety checklist intended to serve as a guide to assure that all aspects of test operating safety have been properly considered. Ames and/or Contractor personnel will initial and date all items pertinent to the proposed tests and receive Ames management approval before tests will be permitted to start.

TABLE I.- MODEL MOTORS

Horse-power	Fre-quency	Rated rpm	Maximum rpm	Number of poles	Full load amps	Rated volts	E/f	Case diameter "D" in.	Case length "L" in.	$K_t = HP_t/ND^2Lx$ 10^{-5}	Manufacturer	Number of motors
3	300	18,000	18,000	2	4.69	360	1.2	2	6-3/4	.618	Sawyer	2
8	300	18,000	24,000	2	15.0	300	1.0	3-1/4	6-5/8	.635	--do.--	6
22	200	12,000	16,000	2	61.9	200	1.0	4-1/2	12	.754	--do.--	3
33	400	12,000	12,000	4	38.7	480	1.2	5-1/2	10	.910	--do.--	2
45	300	9,000	9,000	4	70.4	360	1.2	7	14	.728	--do.--	2
75	333-1/3	10,000	10,000	4	106	400	1.2	8	14-1/2	.890	--do.--	2
63	300	18,000	18,000	2	120	360	1.2	4-1/4	12	1.615	Hare	5
62	120	7,200	9,000	2	242	144	1.2	7-1/4	16	1.02	Sawyer	4
110	333-1/3	10,000	10,000	4	156	400	1.2	8	16	1.07	Byron Jackson	2
125	350	7,000	7,000	6	168	420	1.2	9	24-1/2	.90	Sawyer	2
96	350	7,000	7,000	6	168	440	1.25	9	24-1/2	.68	Amer. Elec.	1
120	96-2/3	5,800	7,200	2	291	290	3.0	10	20	.825	General Elec.	2
120	96-2/3	5,800	7,200	2	290	330	3.5	10	20	.825	--do.--	1
120	96-2/3	5,800	7,200	2	290	290	3.0	10	20	.825	Amer. Elec.	1
150	300	18,000	18,000	2	235	360	1.2	7	18-1/2	.92	Sawyer	2
250	120	3,600	4,500	4	160	880	7.33	13-1/2	30	1.21	General Elec.	2
250	120	3,600	3,600	4	160	880	7.33	13-1/2	30	1.21	--do.--	2
300	300	18,000	20,000	2	468	360	1.2	11-3/4	22	.76	--do.--	4
300	600	18,000	18,000	4	415	400	0.66	10	22	.76	--do.--	2
350	150	4,500	4,500	4	359	550	3.66	10	41	1.98	--do.--	1
400	120	2,400	2,400	6	256	880	7.33	22	38	.91	Sawyer	2
600	150	4,300	4,500	4	315	1,100	7.33	19	32	1.21	Byron Jackson	4
700	600	18,000	20,000	4	535	750	1.14	14	24	.827	General Elec.	2
800	400	12,000	15,000	4	810	500	1.25	14	24	1.415	Hare	2
1,000	120	2,400	3,000	6	641	880	7.33	28	38	1.50	General Elec.	5
1,000	120	2,400	3,000	6	640	880	7.33	28	38	1.50	--do.--	4
1,000	110	6,600	7,200	2	575	880	8	20	38	1.00	Amer. Elec.	2
1,500	150	3,000	3,000	6	768	1,100	7.33	28	50	1.27	General Elec.	2

TABLE II.- SCALE BALANCE SYSTEM "LEAST COUNT" SENSITIVITY

	Optical scanners	Printed paper tape	Self-balancing servos (IMP's)[2]
Lift,[1] lb	5	10	12
Drag, lb	1	2	2.4
Side Force,[1] lb	1	2	2.4
Pitching moment, ft-lb	160	320	384
Rolling moment, ft-lb	85	170	204
Yawing moment, ft-lb	24	48	57.6

[1] Two balances used to measure total force

[2] Normally inactive, but available for special purposes

TABLE III.- DATEX II SPECIFICATIONS

Number of channels	10
Number of step positions	up to 48
Maximum number of d.c. inputs	480
Signal level for full range, continuously adjustable for each channel	5mV to 100V
Digital output for each input	0 to 999 counts
Strip chart width, each channel	10 in
commutating rate, maximum	100 steps/min
commutating rate, minimum	6 steps/min
Chart speed	1 in/hr to 2 in/sec
Manual decimal decades available	28
" sign switches available	10

Common mode voltage rejection
Greater than 100db at 59, 61, and 119 Hz on the 5mV range

System noise $\pm 2.5\ \mu V$ referred to the input with 350Ω termination

System linearity $\pm 0.1\%$

Table IV.- Analog Tape Recorder System Specifications

(a).- Differential Amplifiers

These specifications apply to a standard Accudata VI Amplifier fitted with a Type D Attenuator only.

Gain	10-1,000 (7 steps)
Gain accuracy	DC Accuracy ±0.1% with potentiometer CCW
Gain stability	DC Stability ±0.1% with potentiometer CCW
Input impedance	100 Meg Ω Shunted by 500 mmfd
Maximum source impedance	1 KΩ
Maximum source unbalance	1 KΩ
Drift	Less than 4μv (24 hrs) at const amb temp
Settling time	200μ sec (nominal 1.0%)
Operating ambient temp	0^{o} to 50^{o} C
Noise (Referred to input) 0-50KC	5μv rms (with shorted source)
Chopper intermodulation	0.2%
Frequency response	±1.0% to 1KC ±2db to 10KC
DC linearity	0.1%
Common mode rejection	160db at DC 120db at 60 cps 100db at 1 KC
DC output impedance	100 milliohms
Output capability	±10v at 100 milliamps DC or peak AC, to 5KC
Capacitive output load	0.25mfd or K/338 mfd, whichever is less, where K is amplifier gain
Overload recovery for 100% Overload	500 milliseconds (gains 200-1000) 1500 milliseconds (gains 10-100)(typical)
Power requirements	115±10v, 50 to 400 cps, 15 watts

Note: These specifications are valid only when the amplifier is used as indicated, with the associated equipment recommended.

Table IV.- Continued.

(b).- Honeywell LAR 7470/7490 Frequency Modulation Record/Reproduce System

When high degrees of amplitude accuracy and stability and/or the recording of dc or very low frequency data are required, the wide deviation frequency modulation recording technique is employed. The FM record module, essentially a voltage controlled oscillator, amplifies the input data signal and converts it into a carrier frequency deviation proportional to the amplitude of the input signal. The resulting carrier is amplified to drive the record head to tape saturation level. The center frequency of the oscillator, dependent upon tape speed is determined by precision core. When recovering the signal from the magnetic tape, the output of the playback head is amplified by a head preamplifier on the transport and is fed to the FM reproduce module, where it is amplified and precisely limited. The limiter section drives a diode discriminator which is followed by an output or power section. The limiter output may also be used to drive a record head on another transport for duplicating tape without demodulating the head.

Input level	0.5 to 12 volts rms for ±40% carrier deviation. 0.25 to 6 volts rms for ±20% carrier deviation. Adjustable by means of front panel control.
Input impedance	10,000 ohms, unbalanced to ground.
DC linearity	Less than ±1% of peak-to-peak output deviation from best straight line through zero center (±40% deviation system).
Total harmonic distortion	Less than 1.5%.
Zero drift	Less than ±1% of peak-to-peak output for eight hour period after 1/2 hour warmup (±40% deviation system).
Sensitivity drift	Less than ±0.5% of peak-to-peak output for eight hour period after 1/2 hour warmup.
Phase response	.02 deg/cps phase lag.
Output level	0 to 4 volts peak continuously variable by means of front panel control (±40% deviation).
Output current	30 milliampers maxium, 4 volts peak (standard).
Output impedance	Less than 1 ohm, shortcircuit-proof.

Table IV.- Continued.

(b).- Concluded.

Extended Response

Tape speed ips	Frequency response (full scale input) cps $\pm$ 0.5 DB	Center frequency KC	Signal/noise ratio
60	DC - 20,000	108.0	Rep. at 30 ips or less
30*	DC - 10,000	54.0	48
15	DC - 5,000	27.0	46
7-1/2*	DC - 2,500	13.5	44
3-3/4	DC - 1,250	6.75	43
1-7/8	DC - 625	3.38	40
0.6	DC - 200	1.08	36

*Currently available at the 40- by 80-foot wind tunnel.

Signal/noise ratio is defined as the ratio of a full scale input sine wave to residual system noise with the recording input shorted. Electronic compensation will increase above figures by as much as 10 DB to a maximum of 50 DB (optional).

Table IV.- Concluded.

(c).- Honeywell Series 3170 Tape Transport.

Designed and constructed to meet the demanding requirements of laboratory recording applications, the Honeywell Series 3170 closed-loop tape path transports offer many unique performance and convenience advantages to instrumentation magnetic tape users. These tape transports, with individually controlled reel torque motors and electric dynamic braking for low, uniform tape tension throughout all operating modes, assure extremely accurate reproduction of high frequency direct or DC to medium frequency FM recorded data.

Reel size	14 inch or smaller, precision or standard NAB. 1 inch hub airborne reels optional.
Standard tape widths	1/4, 1/2, 1 inch, or 1, 1-1/2, 2 inch.
Speed selection	Electrical, by means of single front panel switch for six speeds.
Standard tape thicknesses	1.0 or 1.5 mil base without modification. Tapes as thin as 0.65 mil base standard with slight degradation in some specifications. Thinner bases (0.35 mil minimum) on special order.
Start time	Less than 2 sec. at 30 or 60 ips. Less than 1 sec. at slower speeds. Pressure roller engagement at 12 ips and higher speeds is delayed by speed sensing circuit to preclude tape stretch or spillage.
Stop time	Less than 1.5 sec. from 60 ips. Less than 1 sec. from any lower speed.
Tape guiding	Combination of crowned roller and edge guiding techniques for improved tracking and prolonged life of tape edges.
Tape skew	Less than ±300 microinches per inch of tape width.
Timing accuracy	±150 milliseconds per minute at 60 ips (without servo speed control).
Head preamplifiers	Permit playback at all speeds (from 0.6 ips to 60 ips) without head changes.
Tape speed accuracy	±0.25% of nominal at 30 or 60 ips. ±0.5% of nominal at other speeds as low as 1.5 ips. Less than ±0.25% speed change from beginning to end of reel at any tape speed.

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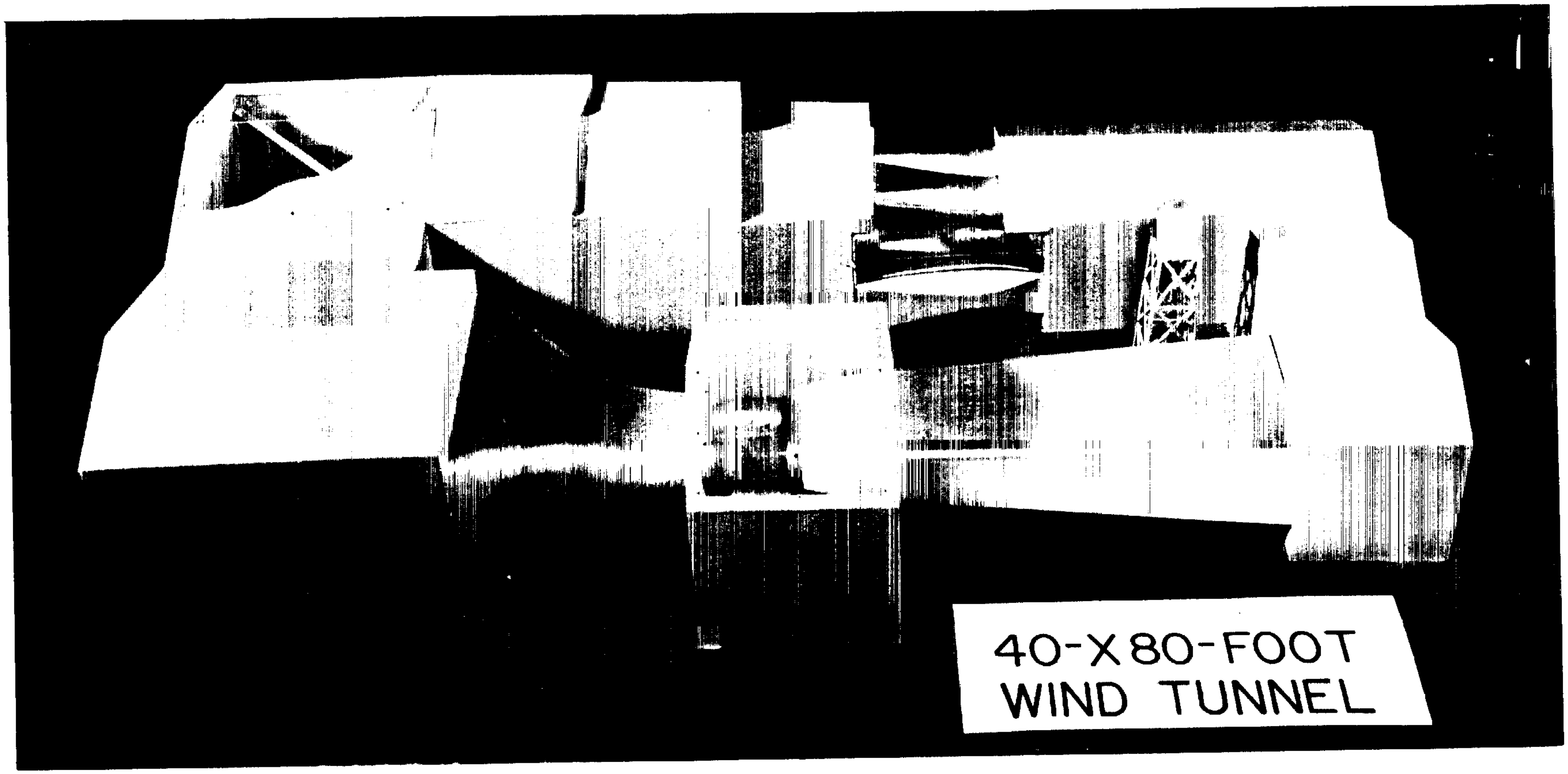

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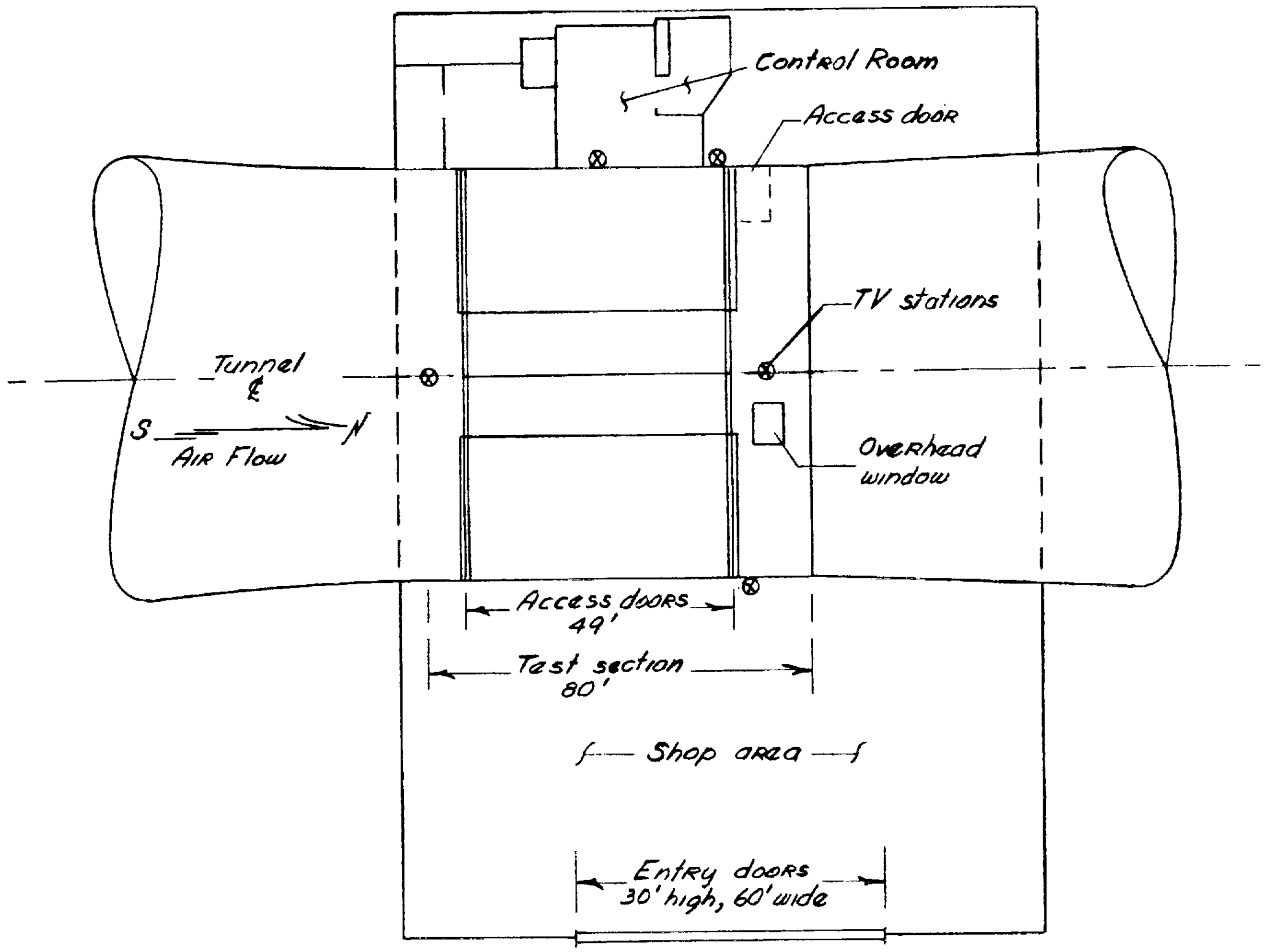
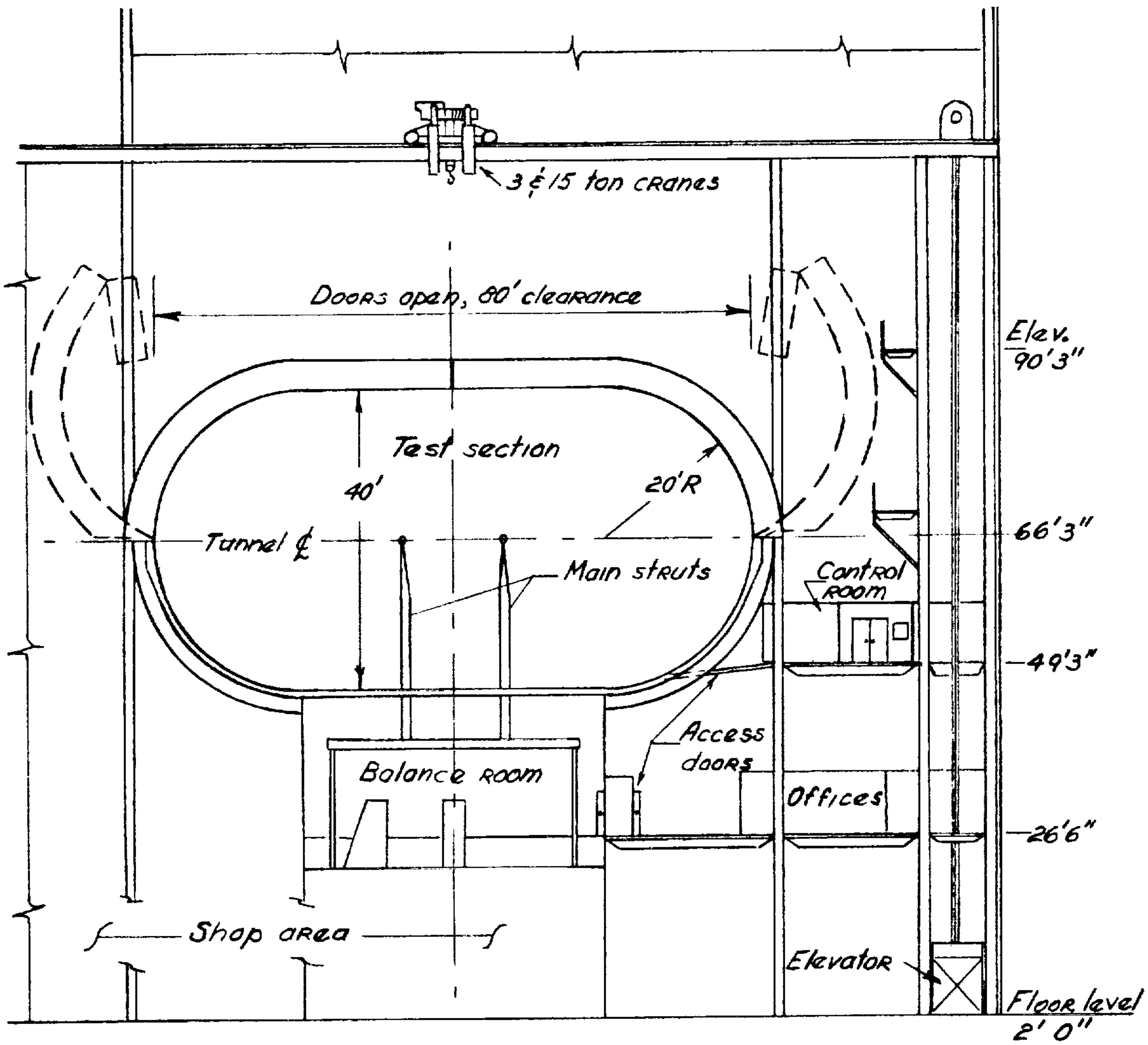
Figure 1.- Scale model of the Ames 40- by 80-foot wind tunnel.



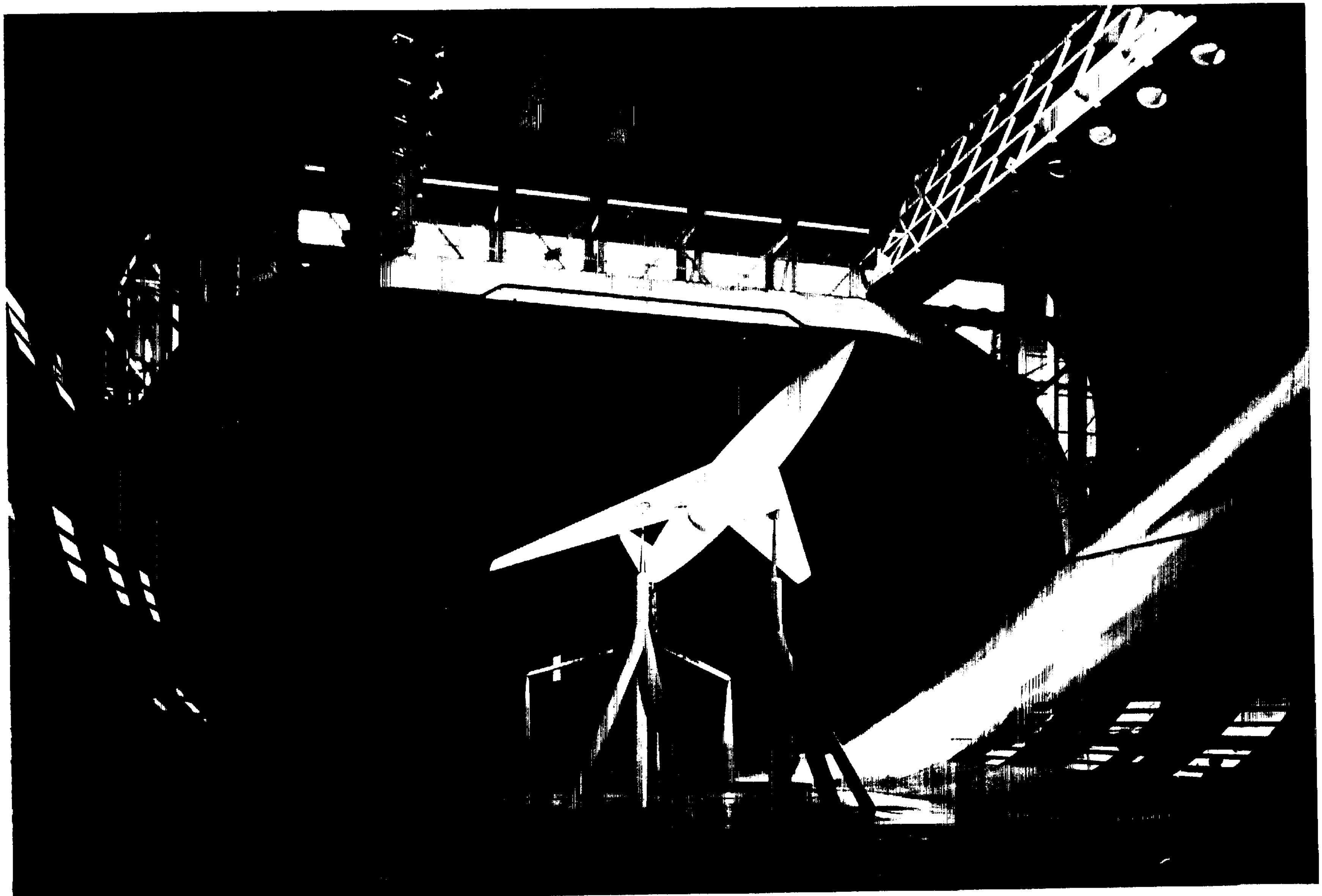
(a) Plan view.

Figure 2.- General arrangement of the Ames 40- by 80-foot wind tunnel test section and shop area.



(b) Elevation view.

Figure 2.- Continued.



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(c) Looking downstream in the test section.
(Overhead doors partially open.)

Figure 2.- Concluded.

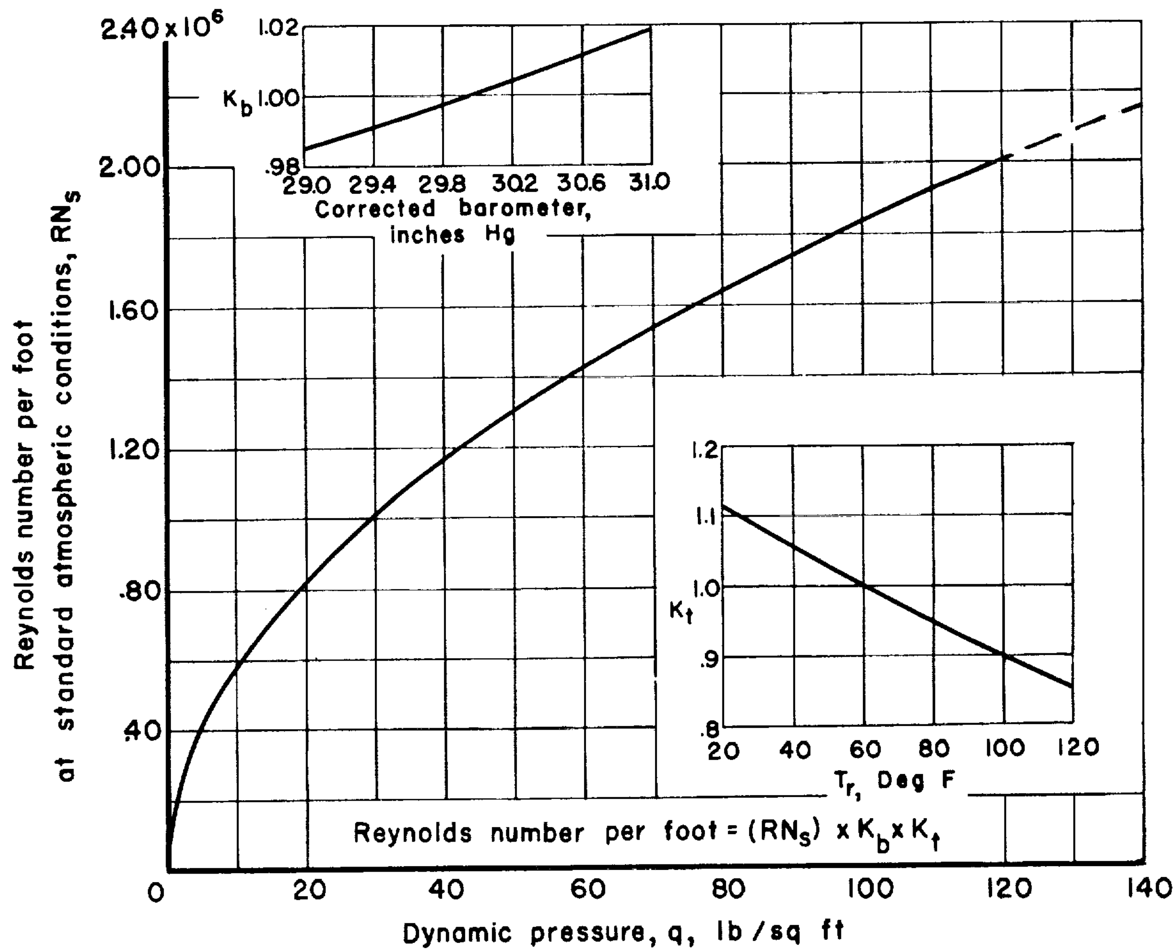
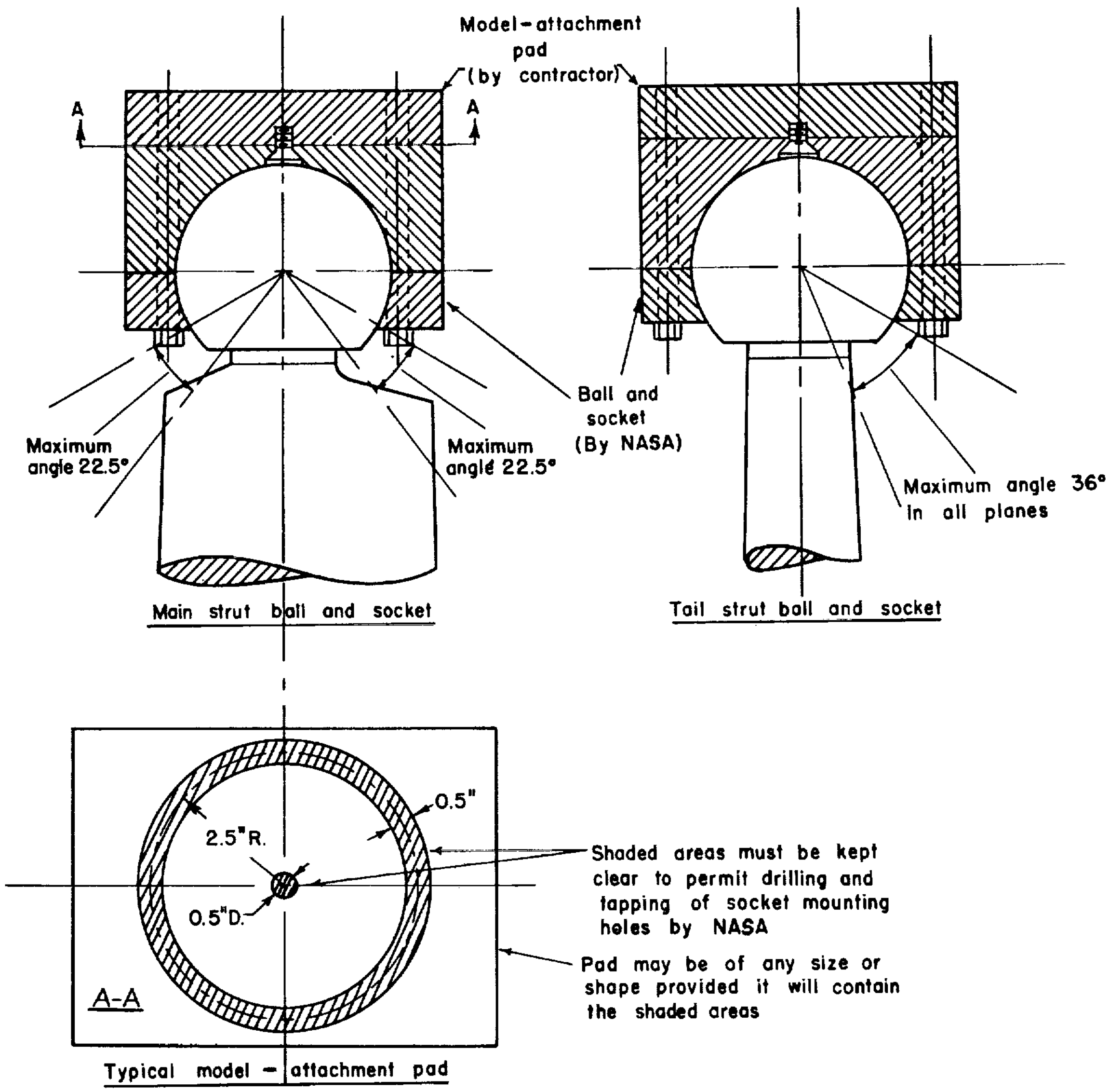
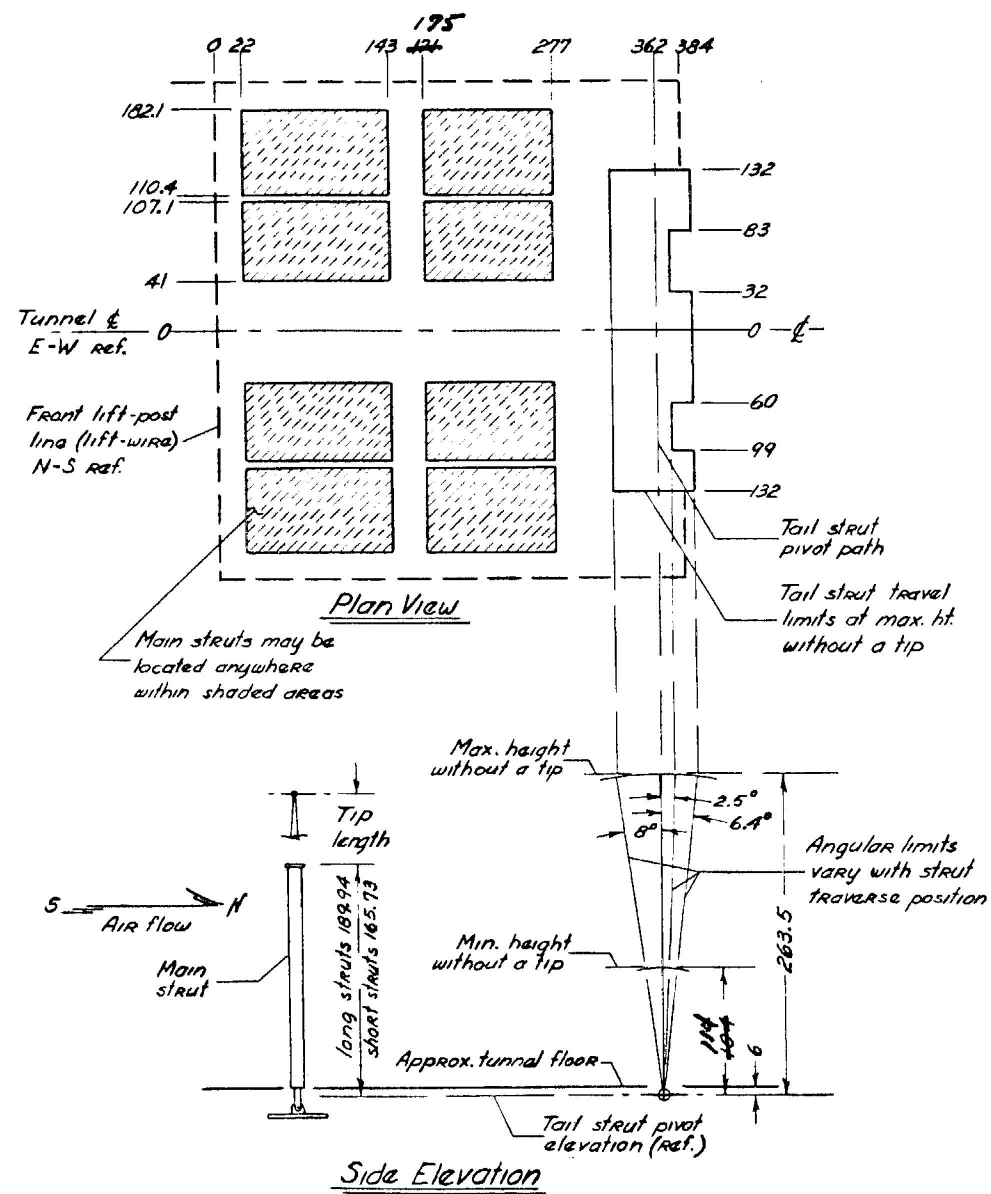


Figure 3.- Variation of Reynolds number with test-section dynamic pressure for the Ames 40- by 80-foot wind tunnel.



(a) Angular limitations of model-support strut tips.

Figure 4.- Limitations and possible arrangements of the primary model-support system in the Ames 40- by 80-foot wind tunnel.



NOTES

1. Strut tip lengths available:
   Main struts 6.63, 38.00, 57.25 inches
   Tail strut 15, 22, 46.3 inches

2. If the airplane is to be tested only at zero yaw, the main struts may be located anywhere within the indicated boxes. (The present system cannot accommodate airplanes having treads[1] from 214.25 to 220.75 inches.) Models having tail lengths[2] from 187 to 225 inches may be severely limited in angle of attack.

3. If the airplane is to be yawed, the yaw angle available is determined by the airplane tread and tail length and the proximity of the main struts to the boundaries described in note 2. The maximum allowable movements of the main struts are 17 inches cross stream and 54 inches streamwise. It is suggested that the available yaw angle be estimated by the 40- by 80-foot wind-tunnel staff upon receipt of values of tread and tail length compatible with the above requirements and the structure of the model.

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[1]For wind-tunnel purposes, the tread is defined as the distance between the main strut attachment points.

[2]Tail length is defined as the horizontal distance from the main strut center line to the center line of the tail strut ball socket.

(b) Limitations of model tread, tail length, and yaw.

Figure 4.- Concluded.

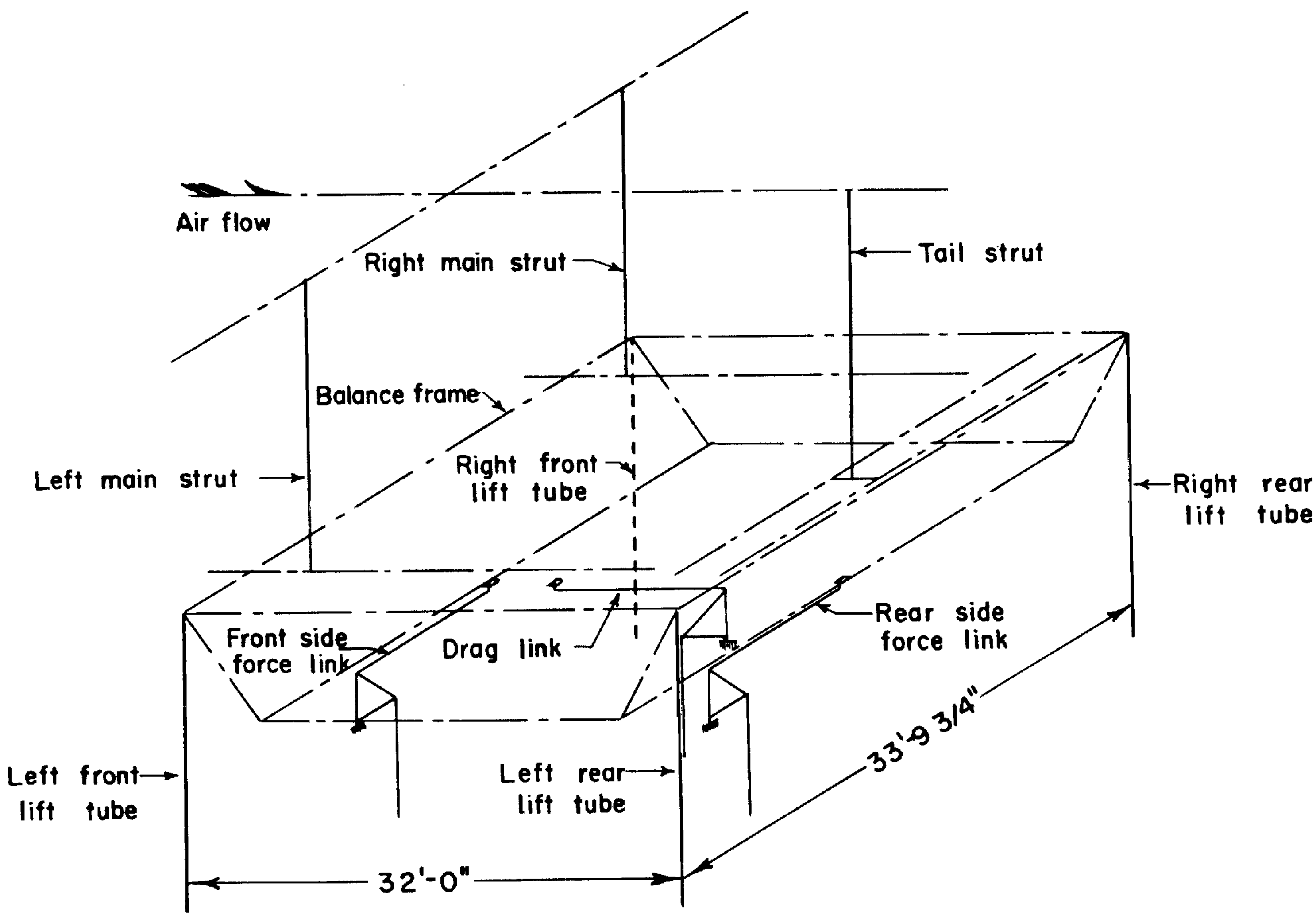

Figure 5.- Schematic representation of the Ames 40- by 80-foot wind tunnel balance system.

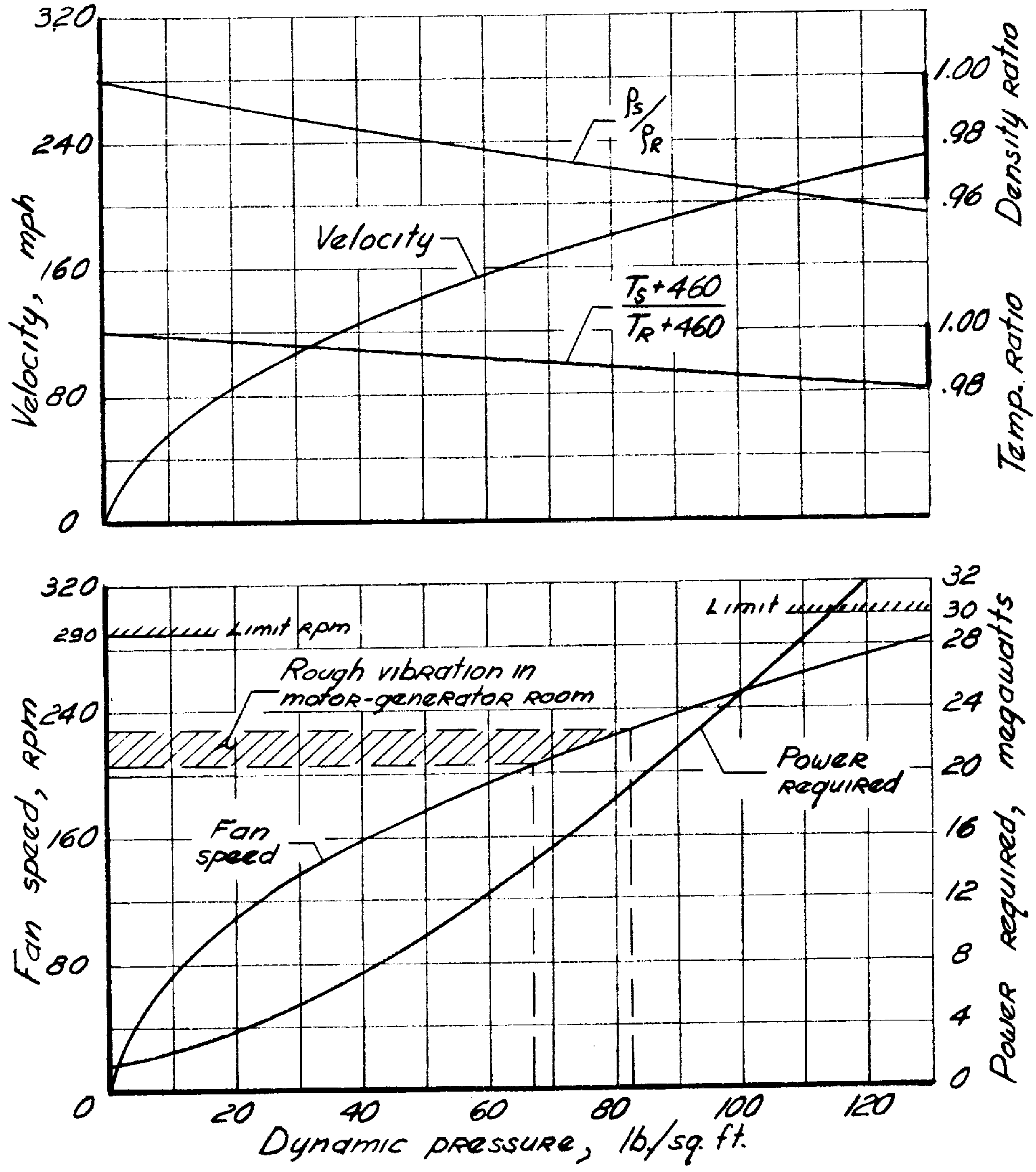

Figure 6.- Variation of test-section conditions and operating characteristics with test section dynamic pressure at standard atmospheric conditions without a model installed. Ames 40- by 80-foot wind tunnel; primary model support system.

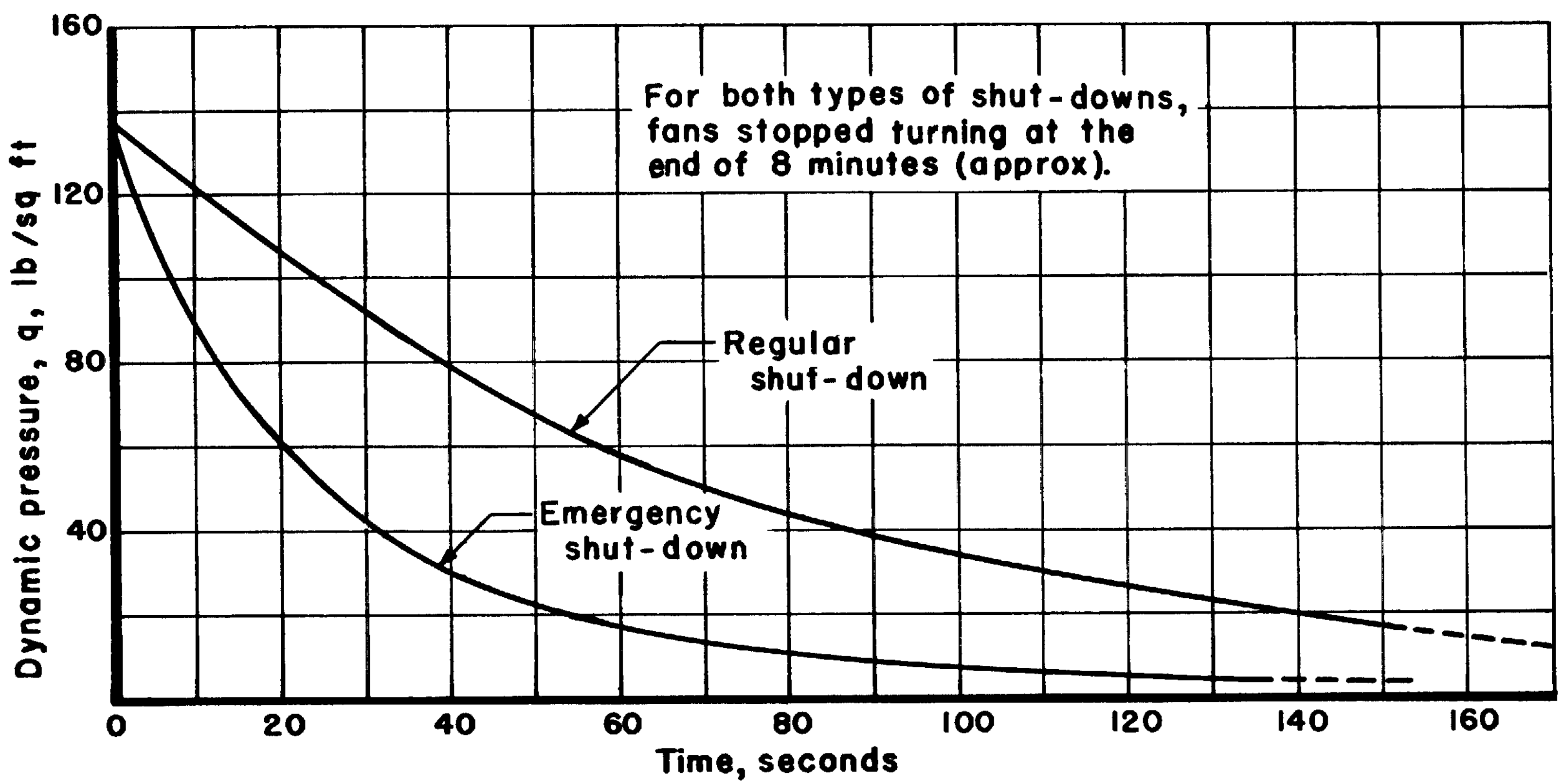

Figure 7.- Time histories of conventional and emergency shutdowns of the 40- by 80-foot wind tunnel from maximum tunnel airspeed.

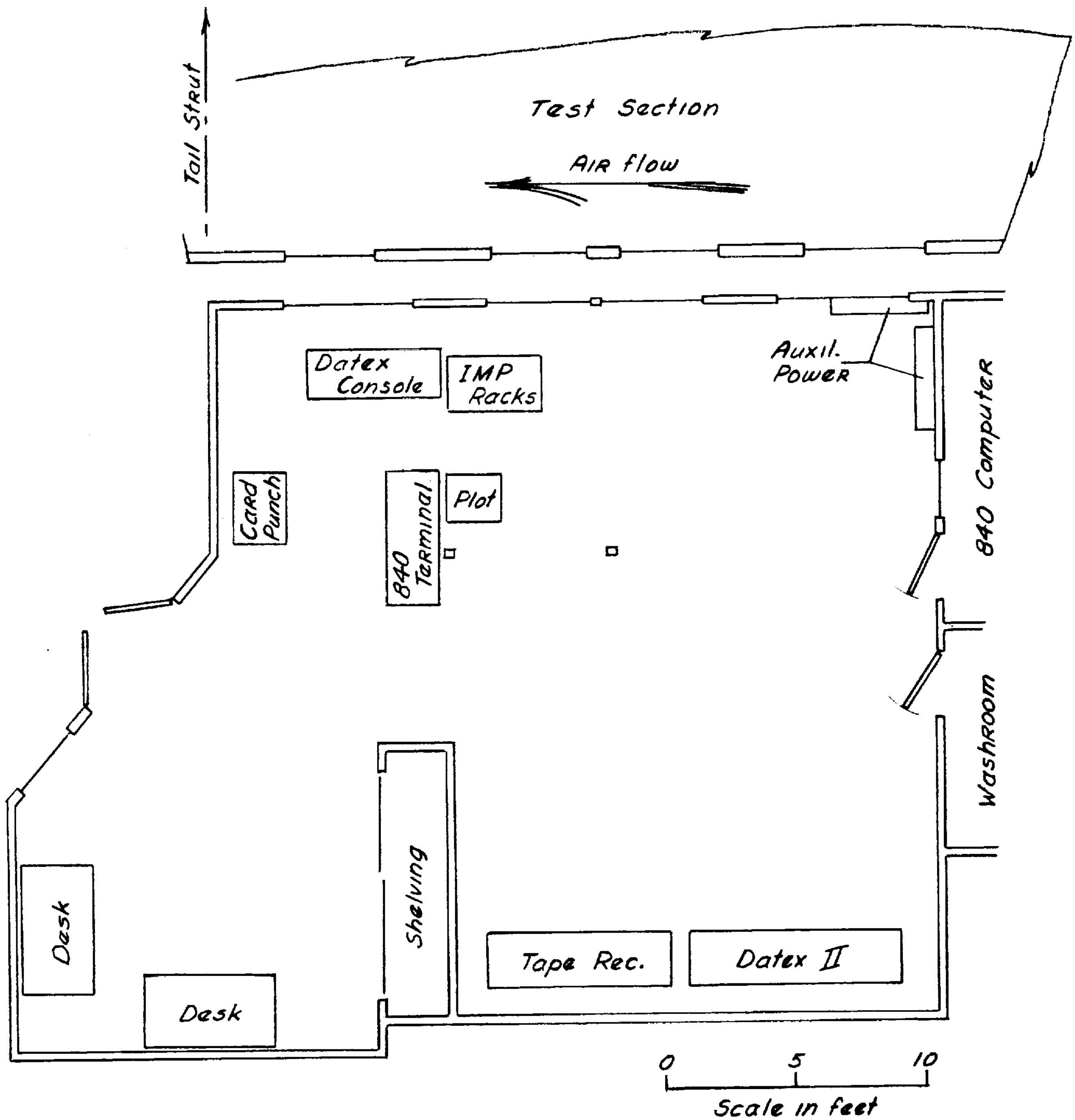

Figure 8.- Control room layout.